

# Width of Radio-Loud and Radio-Quiet CMEs

G. Michalek<sup>1</sup>, N. Gopalswamy<sup>2</sup>, H. Xie<sup>3</sup>

<sup>1</sup> *Astronomical Observatory of Jagiellonian University, Cracow, Poland*  
(michalek@oa.uj.edu.pl)

<sup>2</sup> *Solar System Exploration Division, NASA GSFC, Greenbelt, Maryland*

<sup>3</sup> *Center for Solar and Space Weather, Catholic University of America*

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**Abstract.** In the present paper we report on the difference in angular sizes between radio-loud and radio-quiet CMEs. For this purpose we compiled these two samples of events using Wind/WAVES and SOHO/LASCO observations obtained during 1996-2005. It is shown that the radio-loud CMEs are almost two times wider than the radio-quiet CMEs (considering expanding parts of CMEs). Furthermore we show that the radio-quiet CMEs have a narrow expanding bright part with a large extended diffusive structure. These results were obtained by measuring the CME widths in three different ways.

**Keywords:** Sun: solar activity, Sun: coronal mass ejections, Sun: solar radio emission

## 1. Introduction

The relation between coronal mass ejections (CMEs) and type II radio bursts has been studied for a long time, but is not fully understood (see Gopalswamy (2006) for a recent review). Properties of the driving CMEs and the ambient medium through which the CMEs drive shocks show a large variability, which seems to contribute to the difficulties faced in understanding them (Gopalswamy *et al.*, 2001). One of the major issues has been the lack of the type II radio emission in the metric (Sheeley *et al.*, 1984) and decameter-hectometric (DH) wavelengths (Gopalswamy *et al.*, 2001) even for CMEs with speeds exceeding  $1000 \text{ km s}^{-1}$ . Recently, Gopalswamy *et al.* (2007) performed a systematic investigation of fast and wide (FW) CMEs that clearly lacked the metric and DH type II radio emission (“radio-quiet” CMEs) and compared them with the ones (“radio-loud” CMEs) producing detectable radio type II. It was found that the radio-quiet CMEs can be distinguished from the radio-loud CMEs in three aspects: (1) speeds and widths, (2) a fraction of halo CMEs, and (3) solar source location of the CMEs. The radio-quiet CMEs are generally slower and narrower than the radio-loud ones. The fraction of halo CMEs is much larger for the radio-loud CMEs, which is related to the fact that the radio-quiet CMEs are narrower on the average. It is also known that halo CMEs are also faster and wider on the average (Yashiro *et al.*, 2004; Michalek, Gopalswamy, and Yashiro, 2003; Gopalswamy, 2004). When the source locations were examined, Gopalswamy (2006) and Gopalswamy *et al.* (2007) found that more than half of the

radio-quiet CMEs were back-sided, while only a small fraction (25) of the radio-loud CMEs were back-sided. They attributed this result to the possibility that only a small fraction of the shock surface is visible to the observer, thereby reducing the possibility of detecting significant radio emission. A fast but narrow CME may have a similar limitation because the CME cross-section and hence the shock surface area are expected to be smaller. One of the suggestions made in Gopalswamy *et al.* (2007) is that most of the radio-quiet CMEs may have a narrow bright part with extended diffuse structure. The purpose of this paper is to examine the evolution of the width of radio-quiet and radio-loud CMEs and compare them to confirm the smaller width of CMEs as a contributor to radio quietness.

In Section 2 the procedure for obtaining the samples of the radio-loud and radio-quiet CMEs is presented. In this section three different methods for the determination of CME widths are also explained. In Section 3, we use the measured CME widths to show the spatial difference between the radio-loud and radio-quiet CME populations.

## 2. Data and Determination of CME Width

We consider the width evolution of radio-loud and radio-quiet CMEs in the period of time from the beginning of SOHO/LASCO observations (1996) until the end of 2005. For this purpose we used observational data from two instruments: The Radio and Plasma Wave Investigation on the WIND Spacecraft (Wind/WAVE, Bougeret *et al.*, 1995) and the Large Angle Spectroscopic Coronagraph on the SOHO Spacecraft (SOHO/LASCO, Brueckner *et al.*, 1995). To get more accurate estimation of spatial sizes of the radio-loud and radio-quiet CMEs additional determination of their width were made. Details of these measurements are described in the next two subsections.

### 2.1. DATA

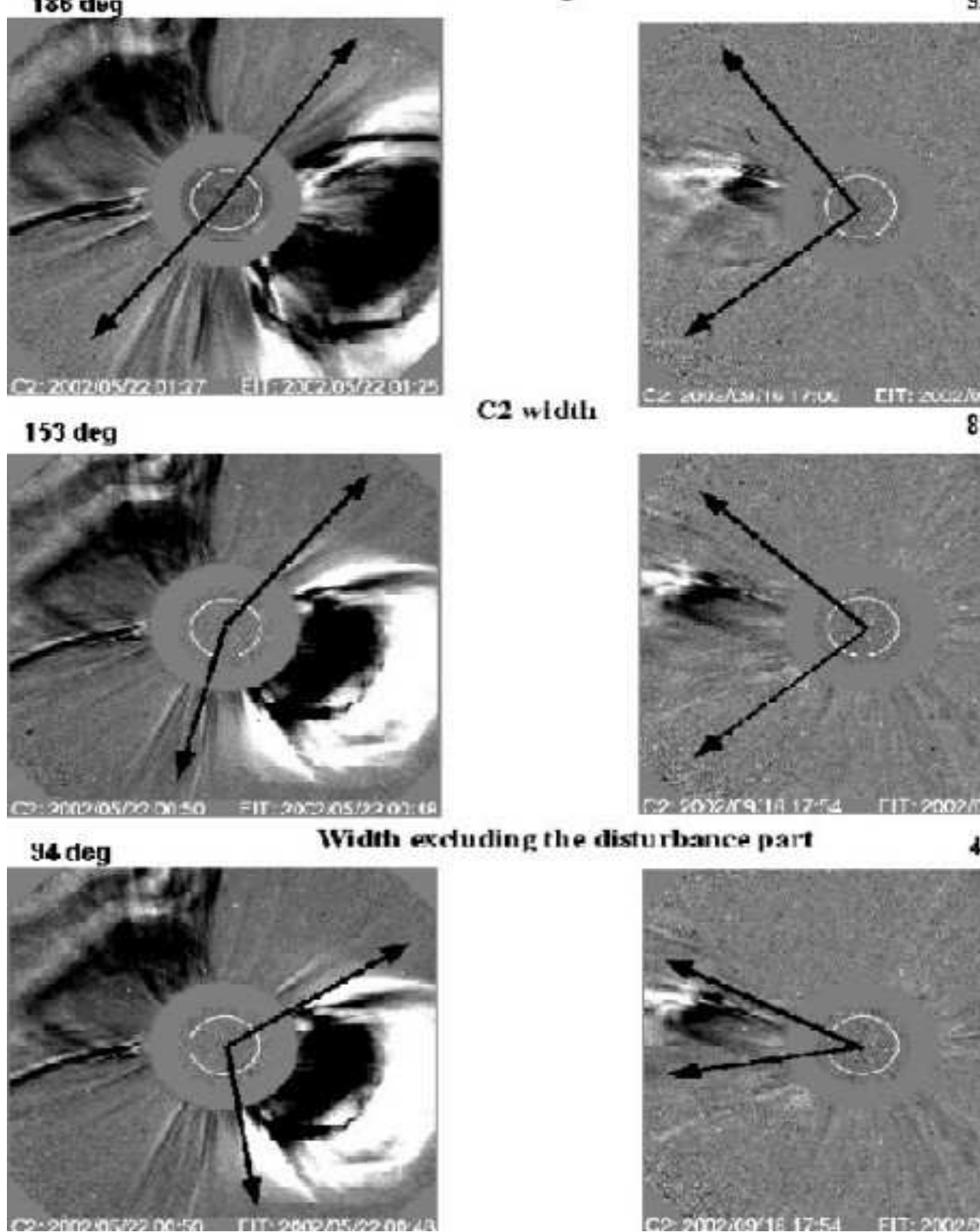
The radio bursts were identified in the dynamic spectra of the Radio and Plasma Waves (WAVES) Experiment. The radio-loud and radio-quiet CMEs are the two subsets of fast and wide CMEs ( $\text{speed} \geq 900 \text{ km s}^{-1}$  and  $\text{width} \geq 60^\circ$ ). Gopalswamy *et al.* (2007) used the speeds and widths available in the on-line catalog ([http://cdaw.gsfc.nasa.gov/CME\\_list](http://cdaw.gsfc.nasa.gov/CME_list)). Here we measure the widths again especially to follow the evolution of the width. There were 469 FW CMEs, of which 195 were radio-quiet and 274 were radio-loud. The full list of the radio-loud and radio-quiet CMEs and their properties are presented in Gopalswamy (2007). The list excludes the three-month period (Jun to October 1998) when SOHO was temporary unavailable.

## 2.2. WIDTH DETERMINATION

One of the interesting facts is the size difference between the radio-loud and radio-quiet CMEs. For this purpose we measured widths of CMEs in three different ways. In Figure 1, examples of width determination for typical radio-loud (2002/05/22) and radio-quiet (2002/09/16) events are displayed. First, in the top two panels we explain the method used for measurements employed for SOHO/LASCO catalog (Yashiro *et al.*, 2004). In this method the CME width is measured in LASCO C2 field of view (FOV) when CMEs reach the largest angular size. Such a situation normally takes place in the late phase of the propagation of CMEs when their leading edges are observed in LASCO C3 FOV. The middle two panels show the second method of width determination. The method is similar to the catalog method, but now widths are measured when the leading edges of CMEs reach the boundary of LASCO C2 FOV. It is clear that during the expansion, especially for the very fast events, coronal plasma is compressed. These disturbances appear as bright structures in LASCO observations influencing the width determination. These disturbances do not give any addition to type II radio emission. To get a more accurate space dimensions of the radio-loud and radio-quiet CMEs, we decide to determine the width only from the main body of CMEs. For this purpose we measured the width excluding the disturbance part. Examples of such measurements are presented in the bottom two panels in Figure 1. This is the third method.

## 3. Results

We compiled the widths for all the radio-loud and radio-quiet CMEs using the three methods. Figure 2 shows width distributions for the radio-loud and radio-quiet CMEs taken from SOHO/LASCO catalog. As we can see, in average, the radio-loud CMEs (the average width =  $138^\circ$ ) are about 10% wider than the radio-quiet CMEs (the average width =  $125^\circ$ ). To get more objective results we compare widths excluding halo events. In Figure 3, in two panels, width distributions measured in C2 field of view are displayed. In this phase of evolution the radio-loud CMEs (the average width =  $116^\circ$ ) seem to be about 20% wider than the radio-quiet CMEs (the average width =  $85^\circ$ ). For catalog and C2 measurements, widths of CMEs are distributed over the whole possible angular range ( $0^\circ - 360^\circ$ ). Finally, we considered width distributions determined by excluding the disturbance part. The distributions for the radio-loud and radio-quiet CMEs are shown in Figure 4. As we may see, the radio-loud CMEs (average width =  $69^\circ$ ) are about 40% wider than the radio-quiet CMEs (average width =  $47^\circ$ ). The expanding structures of the radio-quiet CMEs are much narrower in comparison with the radio-loud



*Figure 1.* In the successive panels the three methods of width determination for examples of radio-loud and radio-quiet CMEs are presented.

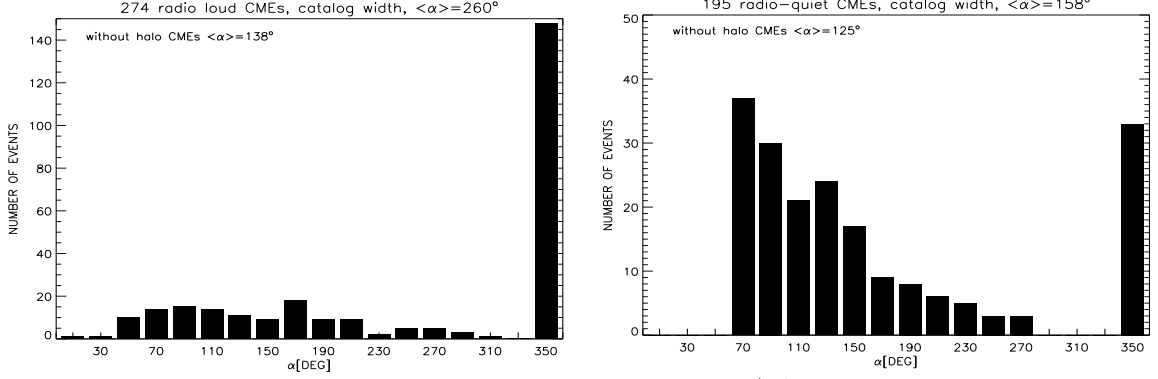


Figure 2. The distributions of CME width measured for SOHO/LASCO catalog for radio-loud (left) and radio-quiet (right) CMEs.

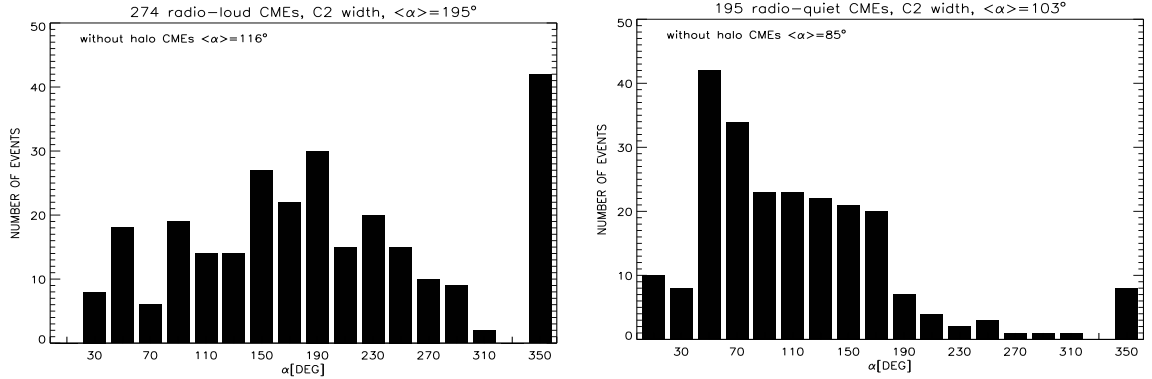


Figure 3. The distributions of CME width measured during transit from C2 to C3 LASCO fields of views for radio-loud (left) and radio-quiet (right) CMEs.

CMEs. Now, the measured widths are distributed over a smaller angular range ( $0^\circ - 270^\circ$ ). It is interesting that the expanding structures of CMEs are much narrower in comparison with their total widths also. The ratios of the average catalog width to the average main body width are equal about 2.0 and 2.7 for radio-loud and radio-quiet CMEs, respectively.

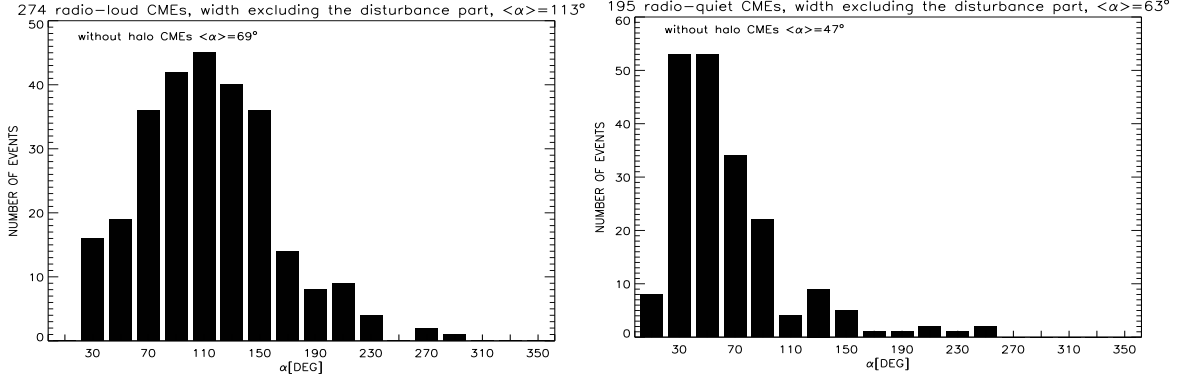


Figure 4. The distributions of CME width excluding the disturbance part for radio-loud (left) and radio-quiet (right) CMEs.

#### 4. Summary

In this study we examined the spatial difference between the radio-loud and radio-quiet CMEs. To get a reliable result, we determined the angular widths of the radio-loud and radio-quiet CMEs using three different methods. In all cases the radio-loud CMEs are wider than the radio-quiet CMEs. When we compare the expanding parts of CMEs (which are responsible for II type radio emission) the width difference between the events is the largest. The expanding structures of the radio-quiet CMEs are narrower ( $\approx 40\%$ ) in comparison with those of the radio-loud CMEs. The expanding structures of CMEs are also much narrower in comparison with their total widths, especially for the radio-quiet events. The ratios of the average catalog width to the average main body width are equal about 2.0 and 2.7 for the radio-loud and radio-quiet CMEs, respectively. The catalog widths for the radio-quiet CMEs are almost three times bigger in comparison with the widths of expanding structures. This means that the radio-quiet CMEs have a narrow expanding bright part with a large extended diffusive structure. It is clear that the spatial size of CME could be one of the most important factors defining the presence of type II radio emission. Our results proved the previous considerations (*e.g.* Gopalswamy *et al.*, 2001, 2005; Pick and Maia, 2005; Subramanian and Ebenezer, 2006). It is commonly accepted that type II radio bursts are radio signatures of coronal MHD-shock waves (Uchida, 1960; Wild, 1962). Flare-related blast waves and shock driven by CMEs have been considered as two possible pistons of metric type II bursts (see *e.g.* Cliver, Webb, and Howard, 1999), while the DH and longer wavelength bursts due to CME-driven shock. CMEless type II bursts (Sheeley *et al.*,

1984) and the discrepancy between the metric and IP type (Reiner *et al.*, 2001) were used to argue against the same shock causing the metric and IP type bursts. Gopalswamy (2006) demonstrated that both these discrepancies could be explained. It seems that CME-driven shock works for the entire interplanetary space but additional mechanism (blast waves) may operate for a narrow region ( $\approx 1R_{\odot}$ ) close to the solar surface. In both cases, the width of CMEs plays an important role in generation of fast particles and radio bursts. Wider a given CME (more energetic event) wider a shock front and larger area where particles can gain energy. Additionally, larger CMEs could in bigger degree destruct magnetic structures in corona and amplify radio emission (*e.g.* Raymond *et al.*, 2000; Pick *et al.*, 2006). This scenario is confirmed by strong correlation between complex type III and type II radio bursts associated with CMEs (Cane, Erickson, and Prestage, 2002; Gopalswamy, 2004).

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